PROTOCOL FOR EQUIPMENT VERIFICATION TESTING FOR ARSENIC REMOVAL

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PROTOCOL FOR EQUIPMENT VERIFICATION TESTING FOR ARSENIC REMOVAL

1.0 INTRODUCTION

This document is the study protocol to be used for verification testing of equipment designed to achieve arsenic removal. In order to participate in the equipment verification process, the equipment Manufacturer is requested to adhere to the requirements of this study protocol in developing a Manufacturer Field Operations Document. The final submission of the Manufacturer Field Operations Document shall:

- include the information requested in this protocol;
    - conform to the format identified herein;
    - and conform to the specific NSF International (NSF) Equipment Verification Testing Plan or Plans related to the statement(s) of capabilities that are to be verified.

The Manufacturer Field Operations Document may include more than one Testing Plan. For example, testing might be undertaken to verify performance of a package plant employing coagulation and filtration for arsenic removal and for removal of microbiological and particulate contaminants or for removal of disinfection byproduct precursors.

This protocol document is presented in two fonts. The non-italicized font provides background information that the Manufacturer may find useful in preparation of the Manufacturer Field Operations Document. *The italicized text indicates specific study protocol deliverables that are required of the Manufacturer and that must be incorporated in the Manufacturer Field Operations Document.*

The following glossary terms are presented here for subsequent reference in this protocol:

- Certification - the attestation that an equipment and/or a device met all applicable requirements, e.g., standard, performance criteria and policies, and continues to meet all applicable requirements.
- Distribution System - a system of conduits by which a primary water supply is conveyed to consumers typically by a network of pipes

- Manufacturer - is a business that assembles and/or sells package plant equipment and/or modular systems. The role of the manufacturer is to provide the package plant and/or modular system and technical support for the verification testing and study. The manufacturer is also responsible for providing assistance to the testing organization during operation and monitoring of the package plant or modular system during the verification testing and study.

- Manufacturer Field Operations Document - document of field testing operations and procedures. Document will be prepared by Manufacturer or by third party on behalf of Manufacturer and will include the specific details of the experimental approach in the section titled Field Operations Procedures.

- Modular System - a packaged functional assembly of components for use in a drinking water treatment system or package plant that provides a limited form of treatment of the feed water(s) and which is discharged to another module of the package plant or the final step of treatment to the distribution system.

- NSF Equipment Verification Testing Plan - specific testing plan for each technology application, such as reverse osmosis package plants or coagulation and filtration package plants. This plan will be developed by NSF for Manufacturer to assist in development of Manufacturer Field Operations Document.

- Plant Operator - the person working for a small water system who is responsible for operating package water treatment equipment to produce treated drinking water. This person also may collect samples, record data, and attend to the daily operations of equipment throughout the testing periods.

- Package Plant - a complete water treatment system including all components from connection to the feed water(s) through discharge to the distribution system

- Study Protocol for Equipment Verification Testing- this document. Protocol will be used for reference during Manufacturer participation in verification testing program;

- Testing Organization - an organization qualified to perform studies and testing of package plants or modular systems. The role of the testing organization is to ensure that there is skilled operation of a package plant during the intense periods of testing during the study and the tasks required by the Study Protocol for Equipment Verification Testing are performed. The Testing Organization is responsible for:

- managing, evaluating, interpreting, and reporting on the data produced by the verification testing and study;
- providing logistical support, scheduling, and coordinating the activities, e.g., establishing a communications network, of all participants in the verification testing and study;
- ensuring that the locations selected for the testing and study have feed water quality consistent with the objectives of the Study Protocol for Equipment Verification Testing.

- Verification - to establish the evidence on the range of performance of equipment and/or device under specific conditions following a predetermined study protocol.

- Water System - the water system that operates package water treatment equipment to provide treated water to its customers.

1.1 Background

U.S. Environmental Protection Agency (EPA) has partnered with NSF, a nonprofit testing and certification organization, to verify performance of small package drinking water systems that serve small communities. It is expected that both the domestic and international markets for such systems are substantial. EPA and NSF have formed an oversight stakeholders group composed of buyers, sellers, and state permitters, to assist in formulating consensus testing protocols. A goal of verification testing is to enhance and facilitate the acceptance of small package drinking water treatment equipment by state drinking water regulatory engineers and consulting engineers while reducing the need for testing of equipment at each location where the equipment use is contemplated.

NSF will meet this goal by working with equipment Manufacturers and other agencies in planning and conducting equipment verification testing, evaluating data generated by such testing and managing and disseminating information. The Manufacturer is expected to secure the appropriate resources to support their part of the equipment verification process, including provision of equipment and technical support.

The verification process established by EPA and NSF is intended to serve as a template for conducting water treatment verification tests that will generate high quality data for verification of equipment performance. The verification process is a model process that can help in moving small package drinking water equipment into routine use more quickly. The verification of an equipment's performance involves five sequential steps :

1. Development of a verification/Manufacturer Field Operations Document;
2. Execution of verification testing;

3. Data reduction, analysis, and reporting;
4. Performance and cost (labor, chemicals, energy) verification;
5. Report preparation and information transfer.

1.2 Objectives

The specific objectives of the equipment verification testing may be different for each Manufacturer, depending upon the statement of capabilities of the specific equipment to be tested. The objectives developed by each Manufacturer will be defined and described in detail in the Manufacturer Field Operations Document developed for each piece of equipment. The objectives of the equipment verification testing may include:

- Generating field data appropriate for verifying the performance of the equipment;
- Generating field data in support of meeting current or anticipated water quality regulations;
- Evaluating new advances in equipment and equipment design.

An important aspect in the development of the verification testing is to describe the procedures that will be used to verify the statement of performance capabilities made for water treatment equipment. A verification testing plan document incorporates the QA/QC elements needed to provide data of appropriate quality sufficient to reach a defensible position regarding the equipment performance. Verification testing conducted at a single site may not represent every environmental situation which may be acceptable for the equipment tested, but it will provide data of sufficient quality to make a judgment about the application of the equipment under conditions similar to those encountered in the verification testing.

It is important to note that verification of the equipment does not mean that the equipment is "certified" by NSF or EPA. Rather, it recognizes that the performance of the equipment has been determined and verified by these organizations.

1.3 Scope

This protocol outlines the verification process for equipment designed to achieve arsenic removal. The scope of this protocol includes Testing Plans for package plants employing coagulation and filtration (CF), lime softening (LS), ion exchange (IE), activated alumina (AA), reverse osmosis (RO), electrodialysis (ED), and electrodialysis reversal (EDR). This protocol is not an NSF or third-party consensus standard and it does not endorse the products or technology described herein.

An overview of the equipment verification process and the elements of the Manufacturer Field Operations Document to be developed by the Manufacturer are described in this protocol document. Specifically, the Manufacturer Field Operations Document shall define the following elements of the verification testing:

- Roles and responsibilities of verification testing participants;
- Procedures governing verification testing activities such as equipment operation and process monitoring; sample collection, preservation, and analysis; and data collection and interpretation;
- Experimental design of the Field Operations Procedures;
- Quality assurance (QA) and quality control (QC) procedures for conducting the verification testing and for assessing the quality of the data generated from the verification testing; and,
- Health and safety measures relating to electrical, mechanical and other safety codes,
- Environmental concerns relating to the disposal of biological and/or chemical wastes.

Content of Field Operations Document:

The structure of the Manufacturer Field Operations Document must conform to the outline below: The required components of the Document will be described in greater detail in the sections below.

- *TITLE PAGE*
- *FOREWORD*
- *TABLE OF CONTENTS -The Table of Contents for the Manufacturer Field Operations Document should include the headings provided in this document although they may be modified as appropriate for a particular type of equipment to be tested.*
- *EXECUTIVE SUMMARY -The Executive Summary describes the contents of the Manufacturer Field Operations Document (not to exceed two pages). A general description of the equipment and the statement of performance capabilities which will be verified during testing shall be included, as well as the testing locations, a schedule, and a list of participants.*
- *ABBREVIATIONS AND ACRONYMS - A list of the abbreviations and acronyms used in the Manufacturer Field Operations Document should be provided*
- *EQUIPMENT VERIFICATION TESTING RESPONSIBILITIES (described in the sections below)*
- *EQUIPMENT CAPABILITIES AND DESCRIPTION (described in the sections below)*
- *EXPERIMENTAL DESIGN (described in the sections below)*
- *FIELD OPERATIONS PROCEDURES (described in the section below)*
- *QUALITY ASSURANCE TESTING PLAN (described in the section below)*

- *DATA MANAGEMENT AND ANALYSIS (described in the section below)*
- *SAFETY AND ENVIRONMENTAL PLAN (described in the section below)*

Manufacturer Responsibilities:

Preparation of a Manufacturer Field Operations Document that includes the information requested and conforms to the requirements stipulated in this protocol document, and the applicable NSF Equipment Verification Testing Plan or Plans.

2.0 EQUIPMENT VERIFICATION TESTING RESPONSIBILITIES

2.1 Verification Testing Organization and Participants

This verification testing program is being conducted by NSF International with participation of manufacturers, under the sponsorship of the EPA Office of Research and Development, National Risk Management Research Laboratory, Water Supply and Water Resources Research Division (WSWRD) - Cincinnati, Ohio. The WSWRD and NSF jointly are administering the Equipment Verification testing Program. The NSF's role is to provide technical and administrative leadership and support in conducting the testing.

The specific responsibilities of each participant are discussed in Section 2.4. The required content of the field operations Manual and the Manufacturer Responsibilities are listed at the end of each section. In the development of a Manufacturer Field Operations Document, Manufacturers shall provide a table which includes the name, affiliation, and mailing address of each participant, a point of contact, their role, and telephone, fax and email address.

2.2 Verification Testing Agreement

After equipment has been accepted by NSF into the Environmental Technology Verification Program, a letter agreement will be signed between the Manufacturer and the NSF. The purpose of the agreement is to specify a framework of responsibilities for conducting the equipment verification testing.

It is important to note that the entire Manufacturer Field Operations Document, including a Quality Assurance Project Plan (QAPP), must be approved by the Manufacturer and the NSF before the verification testing can proceed.

2.3 Organization

The organizational structure for the verification testing showing lines of communication shall be provided by the Manufacturer.

2.4 Verification Testing Site Name and Location

This section discusses background information on the verification testing site(s), with emphasis on the quality of the feed water, which in some cases may be the source water at the site and may include surface as well as ground waters. The Manufacturer Field Operations Document must provide the site names and locations. In most cases, the equipment will be demonstrated at more

than one site. The equipment should be tested under different feed water quality (or source water quality) and where applicable, under seasonal weather conditions (e.g., surface waters).

2.5 Site Characteristics

The Manufacturer Field Operations Document must include a description of the test site. This should include a description of where the equipment will be located. If the feed water is the source water for an existing water treatment plant, the following information should be provided:

- Characteristics of the feed water where it enters the treatment system;
- Sample of the raw water (without the addition of any water treatment chemicals) for use as the feed water to the equipment being tested;
- Pattern of operation of the raw water pumping system (is it continuous or intermittent?);
- Characteristics of the facilities which will be used for handling treated water and waste (i.e., residuals) from the testing program.

For package water treatment plant testing, the following questions need to be answered:

- Can the finished and wastewater flows produced by the equipment being tested be discharged in ways which do not adversely impact the environment?
- Are water pollution discharge permits needed?
- What are the characteristics of the waters which will be receiving these flows?

2.6 Responsibilities

This section identifies the organizations involved in the testing and describes the primary responsibilities of each organization. The responsibilities of the Manufacturer will vary depending on the type of verification testing. Multiple Manufacturer testing at one time is also an option.

NSF and the equipment testing organization shall be responsible for:

- Providing needed logistical support, establishing a communication network, and scheduling and coordinating the activities of all verification testing participants;

- Ensuring that locations selected as test sites have feed water quality consistent with the objectives of the verification testing (Manufacturer may recommend a verification testing site(s));

- Managing, evaluating, interpreting, and reporting on data generated by the verification testing;

- Evaluating and reporting on the performance of the technologies.

The Manufacturer shall be responsible for provision of the equipment to be evaluated. See additional Manufacturer responsibilities listed below.

Content of Manufacturer Field Operations Document Regarding Equipment Verification Testing Responsibilities:

The Manufacturer, in consultation with NSF as the technical lead, shall be responsible for including the following elements in the Manufacturer Field Operations Document:

- *A table which includes the name, affiliation, and mailing address of each participant, a point of contact, their role, and telephone, fax and email address.*

- *Definition of the roles and responsibilities of appropriate verification testing participants.*

- *Organization of operational and analytical support.*

- *List of the site name(s) and location(s).*

- *Description of the test site(s), the site characteristics and identification of where the equipment will be located.*

Manufacturer Responsibilities:

- *Provision of complete, field-ready equipment for verification testing;*

- *Provision of logistical, and technical support, as required.*

- *Provision of assistance to the qualified testing organization during operation and monitoring of the equipment during the verification testing.*

3.0 EQUIPMENT CAPABILITIES AND DESCRIPTION

3.1 Equipment Capabilities

The Manufacturer must provide the water quality objectives to be achieved in the statement of performance capabilities of the equipment to be evaluated in the verification testing. Statements should also be made regarding the applications of the equipment, what advantages it provides over existing equipment and the known limitations of the equipment. The statement of performance capabilities must be specific and be verifiable by a statistical analysis of the data. An example of a satisfactory statement of performance capabilities would be:

> "This reverse osmosis package plant is capable of achieving a minimum of 95 percent arsenic removal when the arsenic in the feed water is between 10 and 200 μg/L."

A statement of performance capabilities such as:

> "This package plant will be capable of meeting the anticipated arsenic MCL on a consistent and dependable basis,"

would not be acceptable.

The statement of performance capabilities shall indicate the range of water quality with which the equipment can be challenged while successfully treating the feed water. Statements of performance capabilities that are too easily met may not be of interest to the potential user, while performance capabilities that are overstated may not be achievable. The statement of performance capabilities forms the basis of the entire equipment verification testing and must be chosen appropriately. Therefore, the design of the Manufacturer Field Operations Document should include a sufficient range of feed water quality to permit verification of the statement of performance capabilities.

3.2 Equipment Description

Description of the equipment to be used in the verification testing program shall be provided by the Manufacturer. Data plates shall be permanent and securely attached to each production unit. The data plate shall be easy to read in English or the language of the intended user, located on the equipment where it is readily accessible, and contain at least the following information:

a) Equipment Name
b) Model #

c) Manufacturer's name and address
d) Electrical requirements - volts, amps, and Hertz
e) Serial Number
f) Warning and Caution statements in legible and easily discernible print size
g) Capacity or output rate (if applicable)

Content of Manufacturer Field Operations Document Regarding Equipment Capabilities and Description:

The Manufacturer shall be responsible for including the following elements in the Manufacturer Field Operations Document. The description of the equipment to be demonstrated should include:

- *A brief introduction and discussion of the engineering and scientific concepts on which the water treatment equipment is based;*
- *Description of the treatment train and each unit process included in the package plant;*
- *A brief description of the physical construction/components of the equipment. Include general environmental requirements and limitations, weight, transportability, ruggedness, power and other consumables needed, etc;*
- *A statement of typical rates of consumption of chemicals and rates of production of wastes (concentrates, residues, etc.);*
- *Definition of the performance range of the equipment;*
- *Identification of any special licensing requirements associated with the operation of the equipment;*
- *Description of the applications of the equipment and what advantages it provides over existing equipment. Provide comparisons in such areas as: treatment capabilities, requirements for chemicals and materials, power, labor requirements, suitability for process monitoring and operation from remote locations, ability to be managed by part-time operators;*
- *Discussion of the known limitations of the equipment. Include such items as the range of feed water quality suitable for treatment with the equipment, the upper limits for concentrations of regulated contaminants that can be removed to concentrations below the*

MCL, level of operator skill required to successfully use the equipment.

4.0 EXPERIMENTAL DESIGN

This section discusses the objectives of the verification testing, factors that must be considered to meet the performance objectives, and the statistical and other means that the NSF will use to evaluate the results of the verification testing.

4.1 Objectives

The objectives of this verification testing are to evaluate equipment in the following areas:

- Performance relative to manufacturer's stated range of equipment capabilities;
- Impacts of feed water quality variations on its performance;
- Logistical, human, and economic resources necessary to operate the equipment;
- Reliability, ruggedness, cost, range of usefulness, and ease of operation.

If the system is tested on surface water feed, additional information required include:

- How well it performs relative to the requirements of the SWTR and any other specific or anticipated water quality regulation;
- How well it performs relative to the performance recommendations for water filtration processes established in the Partnership for Safe Water.

The Manufacturer shall be responsible for selection of those treatment challenges (tests) listed in NSF test plans that are most appropriate for their equipment. For example, if equipment is only intended for use with groundwater, the use of untreated river water as the feed water would not be appropriate.

4.2 Equipment Characteristics

This section discusses factors that will be considered in the design and implementation of the verification testing. These factors include:

- Ease of operation
- Degree of operator attention required
- Response of equipment and treatment process to changes in feed water quality

- Electrical requirements
- Feed water flow requirements
- Discharge requirements (residuals and treated water flows)
- Equipment footprint
- Unit processes included in treatment train
- Chemicals needed

Verification testing procedures will simulate routine conditions as much as possible and in most cases testing may be done in the field; hence in that circumstance field conditions simulation would not be necessary.

4.2.1 Qualitative Factors

Some factors, while important, are difficult or impossible to quantify. These are considered qualitative factors. Important factors that cannot easily be quantified are the portability of equipment and logistical requirements necessary for using it.

Typical qualitative factors to be discussed are listed below, and others may be added. The Manufacturer Field Operations Document should discuss those factors that are appropriate to the test equipment.

- Reliability or susceptibility to adverse environmental conditions
- Effect of operator experience on the treatment results.

4.2.2 Quantitative Factors

Many factors in this verification testing can be quantified by various means. Typical quantitative factors to be discussed are listed below, and others may be added. The Manufacturer Field Operations Document shall discuss those factors that are appropriate to the test equipment.

- Power and consumable supply (such as chemical) requirements
- Cost of operation and waste disposal
- Budget for preventative maintenance
- Length of operating cycle.

These quantitative factors will be used as an initial benchmark to assess equipment performance.

4.3 Water Quality Considerations

Water treatment equipment is used to treat water and change the quality of feed water (or raw water) so it meets the requirements of the Safe Drinking Water Act (SDWA) and amendments to the SDWA and is aesthetically pleasing and palatable. The experimental design shall be developed so the relevant questions about water treatment equipment capabilities can be answered.

Equipment Manufacturers should recognize that it is highly unlikely that any single item of water treatment process equipment can successfully treat any conceivable feed water containing all of the regulated contaminants and produce a treated water that meets the quality requirements for every regulated contaminant. Although multiple processes could be placed in a treatment train to accomplish such a goal, for most public water systems such comprehensive treatment capability is not needed and would not be cost effective. Therefore, drinking water treatment has been focused on improving the water quality aspects of concern for particular locations. The range of contaminants or water quality problems that can be addressed by water treatment equipment varies, and some package treatment equipment can address a broader range of problems than other types. Manufacturers should carefully consider the capabilities and limitations of their equipment and prepare Manufacturer Field Operations Documents that challenge their equipment sufficiently to enable the verification testing to provide a broad market for their products, while recognizing the limitations of the equipment and not subjecting it to testing for contaminant removal when the outcome is known in advance to be failure and the testing would be fruitless. Manufacturers shall use NSF Equipment Verification Testing Plans as the basis for the specific Manufacturer Field Operations Documents.

4.3.1 Feed Water Quality

One of the key aspects related to water treatment equipment performance verification is the range of feed water quality that can be treated successfully, resulting in treated water quality that meets water quality goals or regulatory requirements. As the range of feed water quality that can be treated by the equipment becomes broader, the potential applications for treatment equipment with verified performance capabilities should also increase. Characteristics of feed water quality that can be important for treatment equipment intended for arsenic removal include:

- turbidity, suspended particles
- arsenic concentration
- arsenic species
- other ions in solution, particularly sulfate, fluoride, and silica
- temperature, with temperatures near freezing having potential for the most difficult treatment conditions
- dissolved organic carbon (DOC), total organic carbon (TOC)
- pH, alkalinity, and hardness

- iron and manganese
- total dissolved solids (TDS)

One of the questions often asked by regulatory engineers in approving package water treatment equipment is, "Has it been shown to work on the water where you propose to put it?" By covering a large range of water qualities the verification testing is more likely to provide an affirmative answer to that question.

4.3.2 Treated Water Quality

Treated water quality is very important. If a Manufacturer states that water treatment equipment can be used to achieve a targeted arsenic removal under a range of influent arsenic levels, the verification testing must be performed to confirm this statement. If the Manufacturer states the water treatment equipment can meet other specified regulatory requirements, the verification testing must provide data that support such a statement of capabilities. For example, if the Manufacturer states that this equipment can meet the goals defined in the Surface Water Treatment Rule (SWTR) in addition to arsenic removal, the Manufacturer must demonstrate that the goals stipulated by the SWTR (i.e., filtered water turbidity requirements) are met during the testing.

In addition, the Manufacturer may wish to make a statement about performance capabilities of the equipment for removal of other regulated contaminants under the SDWA.

Furthermore, some water treatment equipment can be used to meet aesthetic goals that are not included as regulatory requirements of the SDWA. Water quality considerations that go beyond regulatory requirements and may be important for some small systems include:

- color, taste and odor
- TDS
- iron and manganese

Finally, other water quality parameters are useful for assessing equipment performance. These may include:

- particle count or concentration
- TOC

The Manufacturer is encouraged to address these factors in the design of the verification testing program.

4.4 Verification Testing Schedule

Verification testing activities include equipment set-up, initial operation, verification operation, and sampling and analysis. Initial operations are intended to be conducted so Manufacturers can test their equipment and be sure it is functioning as intended. If feed water (or source water) quality influences operation and performance of the equipment being tested, the initial operations period serves as the shake-down period for determining appropriate operating parameters.

For water treatment equipment involving coagulation and filtration for arsenic removal, a period of bench-scale testing (jar testing) followed by initial equipment operation may be needed to determine the appropriate coagulant chemical doses and pH values of coagulated water.. Procedures for jar testing are provided in the American Water Works Association's Manual M37, "Operational Control of Coagulation and Filtration Processes."

The times selected for verification testing may need to include cold weather operations because of seasonal water quality variations and because of the impact of cold temperatures on filtration performance:

- cold temperatures (1 ° to 5 °C) can have an adverse affect on some water treatment processes due to the increase in water viscosity at cold temperatures;

- cold temperatures have an adverse effect on the performance of chemical coagulation due to the reduced rate of coagulant reaction and the reduction in interparticle contacts;

- water flows treated by many types of package water treatment equipment are so great (80 to 100 liters/minute, or greater) that use of mechanical refrigeration to attain temperatures of 1° to 5 °C would be prohibitively expensive.

Verification testing with operations for which data are collected and used to verify performance would be done after initial operations are completed. NSF International is to be notified of the date when verification testing is scheduled to begin.

Content of Manufacturer Field Operations Document Regarding Experimental Design:

The Manufacturer shall be responsible for including the following elements in the Manufacturer Field Operations Document:

- *Identification of the qualitative and quantitative factors of equipment operation to be*

addressed in the verification testing program.

- *Identification and discussion of the water treatment problem or problems that the equipment is designed to address, how the equipment will solve the problem, and who would be the potential users of the equipment.*

- *Identification of the range of key water quality parameters, given in applicable NSF Testing Plans, which the equipment is intended to address and for which the equipment is applicable.*

- *Identification of the key parameters of treated water quality that will be used for evaluation of equipment performance for arsenic removal. Parameters of significance for treated water quality were listed above in Section 4.3.2. and in applicable NSF Testing Plans.*

- *Detailed outline of the verification testing schedule, with regard to seasonal testing periods and testing periods at different temperature conditions.*

5.0 FIELD OPERATIONS PROCEDURES

5.1 Equipment Operations and Design

The NSF Verification Testing Plan specifies procedures that shall be used to ensure the accurate documentation of both water quality and equipment performance. Careful adherence to these procedures will result in definition of verifiable performance of equipment. (Note that this protocol may be associated with a number of different NSF Equipment Verification Testing Plans for different types of arsenic removal process equipment.)

Design aspects of water treatment process equipment often provide a basis for approval by state regulatory engineers and can be used to ascertain if process equipment intended for larger or smaller flows than that evaluated in the verification testing program actually involves the same operating parameters that were relevant to the verification testing. Specific design aspects to be included in the Manufacturer Field Operations Document are provided in detail, in the Manufacturer Responsibilities section below.

5.2 Selection of Analytical Laboratory and Field Testing Organization

To assess the performance of the equipment, the water quality attained using the equipment shall be determined by on-site analysis or by an analytical laboratory, by a field operations and testing organization or by a combination of both. The Manufacturer shall use an NSF-qualified testing organization (laboratory or engineering company). The NSF shall provide a list of qualified testing organizations from which Manufacturers can select for submission of analytical samples. For field operations, the Manufacturer shall employ an NSF-qualified field testing organization. These organizations may include engineering consulting firms, universities, or other qualified scientific organizations with experience operating pilot plant equipment.

In addition to NSF qualification, the analytical laboratories selected must also be certified for analysis of water samples for SDWA compliance by one or more states having SDWA primacy. Because of the variability of acceptance of laboratories from state to state, use of an analytical laboratory certified in a large number of states is recommended. Laboratories approved for sample analysis for the EPA's Information Collection Rule would have nationally recognized capabilities. Analytical results from the laboratory are to be provided directly to the NSF to maintain data integrity.

5.3 Communications, Documentation, Logistics, and Equipment

NSF will communicate regularly with the verification testing participants to coordinate all field activities associated with this verification testing and to resolve any logistical, technical, or QA issues that may arise as the verification testing progresses. The successful implementation of the verification testing will require detailed coordination and constant communication between all verification testing participants.

All Manufacturer/NSF field activities shall be thoroughly documented. Field documentation will include field logbooks, photographs, field data sheets, and chain-of-custody forms. The qualified testing organization shall be responsible for maintaining all field documentation. The following guidelines should be followed:

- Field notes shall be kept in a bound logbook
- Field logbooks shall be used to record all water treatment equipment operating data.
- Each page shall be sequentially numbered
- Each page shall be labeled with the project name and number
- Completed pages shall be signed and dated by the individual responsible for the entries.
- Errors shall have one line drawn through them and this line shall be initialed and dated.

All photographs shall be logged in the field logbook. These entries shall include the time, date, subject of the photograph, and the identity of the photographer. Any deviations from the approved final Manufacturer Field Operations Document shall be thoroughly documented in the field logbook and provided to the NSF.

Original field sheets and chain-of-custody forms shall accompany all samples shipped to the analytical laboratory. Copies of field sheets and chain-of-custody forms for all samples shall be provided to the NSF.

5.4 Initial Operations

Initial operations will allow equipment Manufacturers to refine their operating procedures and to make operation adjustments as needed to successfully treat the feed water. Information generated through this period of operation may be used to revise the Manufacturer Field Operations Document, if necessary. A failure at this point in the verification testing could indicate a lack of capability of the process equipment and the verification testing might be canceled.

5.5 Equipment Operation and Water Quality Sampling for Verification Testing

The qualified testing organization will supervise equipment operation and water quality sampling and analysis during the verification phase of testing, using the procedures described below. The

NSF will oversee or audit these activities. All field activities shall conform with requirements provided in the Manufacturer Field Operations Document that was developed and approved for the verification testing being conducted.

If unanticipated or unusual situations are encountered that may alter the plans for equipment operation, water quality sampling, or data quality, the situation shall be discussed with the NSF technical lead. Any deviations from the approved final Manufacturer Field Operations Document shall be thoroughly documented.

During routine operation of water treatment equipment, the following items should be documented and described by the qualified Testing Organization, the Water System, or the Plant Operator:

- Total number of hours during which the equipment was operated each day;
- Number of hours each day during which the operator was working at the treatment plant and performing tasks related to water treatment and the operation of the treatment equipment;
- Tasks performed during equipment operation.

Content of Manufacturer Field Operations Document Regarding Field Operations Procedures:

The Manufacturer shall be responsible for including the following elements in the Manufacturer Field Operations Document:

- *A table summary of the proposed time schedule for operating and testing,*
- *Field operating procedures for the equipment and performance testing, based upon the NSF Equipment Verification Testing Plan, including:*
  - *listing of operating parameters*
  - *ranges for feed water quality*
  - *sampling and analysis strategy.*

Manufacturer Responsibilities:

- *Provision of all equipment needed for field work associated with this verification testing;*
- *Provision of a complete list of all equipment to be used in the verification testing. A table format is suggested;*
- *Provision of field operating procedures.*

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6.0 QUALITY ASSURANCE PROJECT PLAN (QAPP)

The QAPP for this verification testing specifies procedures that shall be used to ensure data quality and integrity. Careful adherence to these procedures will ensure that data generated from the verification testing will provide sound analytical results that can serve as the basis for performance verification.

6.1 Purpose and Scope

The primary purpose of this section is to outline steps that shall be taken by operators of the equipment and by the analytical laboratory to ensure that data resulting from this verification testing is of known quality and that a sufficient number of critical measurements are taken.

6.2 Quality Assurance Responsibilities

The Manufacturer project manager is responsible for coordinating the preparation of the QAPP for this verification testing and for its approval by the NSF. The qualified testing organization project manager, with oversight from NSF, shall ensure that the QAPP is implemented during all verification testing activities.

The entire Manufacturer Field Operations Document including the QAPP must be approved by the Manufacturer and the NSF before the verification testing can proceed. The NSF must review and either approve the QAPP or provide reasons for rejection of the QAPP along with suggestions on how to modify the QAPP to make it acceptable, provided that the Manufacturer has made a good faith effort to develop an acceptable QAPP (i.e. the QAPP is 75 to 80% acceptable with only minor changes needed to produce an acceptable plan. NSF will not write QAPPs for Manufacturers.)

A number of individuals may be responsible for monitoring equipment operating parameters and for sampling and analysis QA/QC throughout the verification testing. Primary responsibility for ensuring that both equipment operation and sampling and analysis activities comply with the QA/QC requirements of the Manufacturer Field Operations Document (Section **6**) shall rest with the qualified testing organization, with oversight by the NSF. QA/QC activities for the equipment shall include those activities recommended by Manufacturer and those required by the NSF to assure the verification testing will provide data of the necessary quality.

QA/QC activities for the analytical laboratory that analyzes samples sent off-site shall be the responsibility of that analytical laboratory's supervisor. If problems arise or any data appear unusual, they shall be thoroughly documented and corrective actions shall be implemented as

specified in this section. The QA/QC measurements made by the off-site analytical laboratory are dependent on the analytical methods being used.

6.3 Data Quality Indicators

The data obtained during the verification testing must be of sound quality for conclusions to be drawn on the equipment. For all measurement and monitoring activities conducted for equipment verification, the NSF and EPA require that data quality parameters be established based on the proposed end uses of the data. Data quality parameters include four indicators of data quality: representativeness, completeness, accuracy, and precision.

Treatment results generated by the equipment must be verifiable for the purposes of this program to be fulfilled. High quality, well documented analytical laboratory results are essential for meeting the purpose and objectives of this verification testing. Therefore, the following indicators of data quality shall be closely evaluated to determine the performance of the equipment when measured against data generated by the analytical laboratory.

6.3.1 Representativeness

Representativeness refers to the degree to which the data accurately and precisely represent the conditions or characteristics of the parameter represented by the data. In this verification testing, representativeness will be ensured by executing consistent sample collection procedures, including sample locations, timing of sample collection, sampling procedures, sample preservation, sample packaging, and sample shipping. Representativeness also will be ensured by using each method at its optimum capability to provide results that represent the most accurate and precise measurement it is capable of achieving.

For equipment operating data, representativeness entails collecting a sufficient quantity of data during operation to be able to detect a change in operations. For most water treatment processes involving arsenic removal, detecting a +/- 10 percent change in an operating parameter (i.e. headloss, pressure) is sufficient. Mixing energies and flows should also be known within +/- 10 percent.

6.3.2 Completeness

Completeness refers to the amount of data collected from a measurement process compared to the amount that was expected to be obtained. For this verification testing, completeness refers to the proportion of valid, acceptable data generated using each method. The completeness objective for data generated during this verification testing is 85 percent.

6.3.3 Accuracy

The definition of accuracy depends on the context, and is defined as the following:

- Water quality analyses - difference between a sample result and the reference or true value for the sample. Loss of accuracy can be caused by:
  - errors in standards preparation
  - equipment calibrations
  - loss of target analyte in the extraction process
  - chemical interferences
  - systematic or carryover of contamination from one sample to the next.
- Equipment operating parameters - difference between the reported operating condition and the actual operating condition.
- Water flow - difference between the reported flow indicated by a flow meter and the flow as actually measured on the basis of known volumes of water and carefully defined times (bucket and stopwatch technique) as practiced in hydraulics laboratories or water meter calibration shops.
- Mixing equipment - difference between an electronic readout for equipment RPMs and the actual measurement based on counted revolutions and measured time.
- Head loss measurement - determined by using measuring tapes to check the calibration of piezometers for gravity filters or by checking the calibration of pressure gauges for pressure filters.

Meters and gauges must be checked periodically for accuracy, and when proven to be dependable over time, the time interval between accuracy checks can be increased.

6.3.4 Precision

Precision refers to the degree of mutual agreement among individual measurements and provides an estimate of random error. For example, precision for pH shall be performed by grabbing a minimum of three samples under the same conditions (i.e. at the same location, the same time, same sampler) for analyses. The variation between the measurements will vary depending on the type of analysis being performed. It is suggested that Table 1020 in *Standard Methods* (18th edition) be used as a guide for the acceptable variation for the different analyses. If the variation between the measurements is greater than what is suggested in this table, steps should be taken to determine the possible sources for the variation and corrected.

6.4 Quality Control Checks

This section describes the QC requirements that apply to both the treatment equipment and the on-site water quality analyses. It also contains a discussion of the corrective action to be taken if the QC parameters fall outside of the evaluation criteria.

The quality control checks provide a means of measuring the quality of data produced. The Manufacturer may not need to use all the ones identified in this section. The selection of the appropriate quality control checks depends on the equipment, the experimental design and the performance goals. The selection of quality control checks will be based on discussions among the Manufacturer and the NSF. Some types of quality control checks applicable to operating water treatment equipment were described in Section 6.3.4.

6.4.1 Quality Control for Equipment Operation

This section will explain the methods to be used to check the accuracy of equipment operating parameters and the frequency with which these quality control checks will be made. A key aspect of the Equipment Verification Testing Program is to provide operating results that will be widely accepted by state regulatory engineers. If the quality of the equipment operating data can not be verified, then the water quality analytical results may be of no value. Because water can not be treated if equipment is not operating, obtaining valid equipment operating data is a prime concern for verification testing.

An example of the need for QC for equipment operations is an incident of state rejection of test data because the treatment equipment had no flow meter to use for determining engineering and operating parameters related to flow.

6.4.2 Water Quality Data

After treatment equipment is being operated and water is being treated, the results of the treatment are interpreted in terms of water quality. Therefore the quality of water sample analytical results is just as important as the quality of the equipment operating data. Most QA plans emphasize analytical QA. The important aspects of sampling and analytical QA are given below:

6.4.2.1 Duplicate Samples

Duplicate samples must be analyzed to determine the precision of analysis. The procedure for determining samples to be analyzed in duplicate shall be provided with the frequency of analysis and the approximate number. In order to ensure data accuracy, at least 10 percent of the arsenic samples analyzed, or one sample, whichever is greater, should be duplicate samples.

6.4.2.2 Method Blanks

Method blanks are used to evaluate analytical method-induced contamination, which may cause false positive results. If false positive results occur, sample analysis must be halted until the source of the false positive has been determined (i.e., instrument, sample bottles, sampler error). Some analytical measurements may be more prone to contamination than other analyses (i.e. samples analyzed for volatile organics may be more susceptible to contamination than for inorganic chemical analyses). The number of method blanks required depends on the sensitivity of the analysis to contamination, but should be no less than 10-percent of the samples, or one sample, whichever is greater.

6.4.2.3 Spiked Samples

The use of spiked samples will depend on the testing program, and the contaminants to be removed. If spiked samples are to be used, specify the procedure, frequency, acceptance criteria, and actions if criteria are not met.

6.4.2.4 Travel Blanks

Travel blanks should be provided to the analytical laboratory to evaluate travel-related contamination. The procedure, frequency, acceptance criteria, and actions if criteria are not met for the travel blanks must be clearly stated. It is recognized that not all analyses may be subjected to contamination due to travel time (e.g., inorganic constituents). In these cases, travel blanks may not be needed on a routine basis if it can be demonstrated that the analyses are not prone to contamination caused by travel time.

6.4.2.5 Performance Evaluation Samples for On-Site Water Quality Testing

Performance evaluation samples are samples whose composition is unknown to the analyst that are used to evaluate analytical performance. Analysis of PE samples shall be conducted before pilot testing is initiated by submission of samples to the analytical laboratory and to the equipment testing organizations, if appropriate. The control limits for the PE samples will be used to evaluate the equipment testing organization's and analytical laboratory's method performance. One kind of PE sample that would be used for on-site QA in most studies performed under this protocol would be a pH PE sample.

PE samples come with statistics about each sample which have been derived from the analysis of the sample by a number of laboratories using EPA-approved methods. These statistics include a true value of the PE sample, a mean of the laboratory results obtained from the analysis of the PE

sample, and an acceptance range for sample values. The analytical laboratory is expected to provide results from the analysis of the PE samples that meet the performance objectives of the verification testing.

6.5 Data Reduction, Validation, and Reporting

To maintain good data quality, specific procedures shall be followed during data reduction, validation, and reporting. These procedures are detailed below.

6.5.1 Data Reduction

Data reduction refers to the process of converting the raw results from the equipment into concentration or other data in a form to be used in the comparison. The procedures to be used will be equipment dependent. The purpose of this step is to provide data which will be used to verify the statement of performance capabilities. These data shall be obtained from logbooks, instrument outputs, and computer outputs as appropriate.

6.5.2 Data Validation

There are two types of data validation which need to be addressed, field data and laboratory data. For the field data (including data collected from field laboratories):

- The operator shall verify the completeness of the appropriate data forms and the completeness and correctness of data acquisition and reduction;
- The field team supervisor or another technical person shall review calculations and inspect laboratory logbooks and data sheets to verify accuracy, completeness;
- Calibration and QC data will be examined by the individual operators and the laboratory supervisor;
- Laboratory and project managers shall verify that all instrument systems are in control and that QA objectives for accuracy, completeness, and method detection limits have been met.

For the laboratory data,

- Calibration and QC data will be examined by the individual analysts and the laboratory supervisor;
- Laboratory managers shall verify that all instrument systems are in control and that QA objectives for accuracy, completeness, and method detection limits have been met.

Analytical outlier data are defined as those QC data lying outside a specific QC objective window

for precision and accuracy for a given analytical method. Should QC data be outside of control limits:

- The analytical laboratory or field team supervisor will investigate the cause of the problem.
- If the problem involves an analytical problem, the sample will be reanalyzed.
- If the problem can be attributed to the sample matrix, the result will be flagged with a data qualifier.
- The data qualifier will be included and explained in the final analytical report.

6.5.3 Data Reporting

This section contains a list of the water quality and equipment operation data to be reported. At a minimum, the data tabulation shall list the results for feed water and treated water quality analyses and equipment operating data. All QC information such as calibrations, blanks and reference samples are to be included in an appendix. All raw analytical data should also be reported in an appendix. All data should be reported in hardcopy and electronically in a common spreadsheet or database format.

6.6 Calculation of Data Quality Indicators

The equations for any data quality indicator calculations employed shall be provided. These include: precision, relative percent deviation, standard deviation, accuracy, and completeness.

6.7 System Audits

On-site system audits for sampling activities, field operations, and laboratories shall be conducted as specified by the NSF Equipment Verification Testing Plan. These audits will be performed by the NSF to determine if the NSF Equipment Verification Testing Plan is being implemented as intended. Separate audit reports will be completed after the audits and provided to the participating parties through the NSF.

6.8 Reports

6.8.1 Status Reports

The equipment testing organization shall prepare periodic reports for the NSF project managers. These reports should discuss project progress, problems and associated corrective actions, and future scheduled activities associated with the verification testing. When problems occur, the Manufacturer and equipment testing organization project managers shall discuss them with the NSF technical lead, estimate the type and degree of impact, and describe the corrective actions taken to mitigate the impact and to prevent a recurrence of the problems. The frequency, format, and content of these reports shall be outlined in the Manufacturer Field Operations Document.

6.8.2 Audit Reports

Any QA audits or inspections that take place in the field or at the analytical laboratory while the verification testing is being conducted shall be formally reported by the equipment testing organizations to the NSF project manager who will forward them to the Manufacturer and NSF QC Manager for appropriate actions.

6.9 Corrective Action

Each Manufacturer Field Operations Document must incorporate a corrective action plan. This plan must include the predetermined acceptance limits, the corrective action to be initiated whenever such acceptance criteria are not met, and the names of the individuals responsible for implementation.

Routine corrective action may result from common monitoring activities, such as:

- Performance evaluation audits
- Technical systems audits

Content of Manufacturer Field Operations Document Regarding Quality Assurance Project Plan:

The Manufacturer shall be responsible for including the following elements in the Manufacturer Field Operations Document:

- *Description of methodology for measurement of accuracy.*
- *Description of methodology for measurement of precision.*
- *Description of the methodology adopted for use of blanks, the materials used in the blanks, the frequency for using blanks, the criteria for accepting blanks and the actions which will be taken if these criteria are not met.*
- *Description of any specific procedures appropriate to the analysis of the PE samples. It has to be clear how these samples are going to be used in the verification testing. One use of PE*

samples is in the conduct of a system audit (see Section 6.7).

- *Outline of the procedure for determining samples to be analyzed in duplicate, the frequency for performing duplicate analyses and approximate number of samples which will be included in this program.*
- *Description of the procedures used to assure that the data are correct.*
- *Listing of equations used for any necessary data quality indicator calculations . These include: precision, relative percent deviation, standard deviation, accuracy, and completeness.*
- *Outline of the frequency, format, and content of reports to be submitted to each party involved in the tests.*
- *Description of the action which will be used to correct problems as they occur during the tests.*

Manufacturer Responsibilities:

- *Provision of all QC information such as calibrations, blanks and reference samples in an appendix. All raw analytical data should also be reported in an appendix.*
- *Provision of all data in hardcopy and electronic form in a common spreadsheet or database format.*

7.0 DATA MANAGEMENT AND ANALYSIS, AND REPORTING

7.1 Data Management and Analysis

The Manufacturer, the qualified testing organization and the NSF each have distinct responsibilities for managing and analyzing verification testing data. The equipment testing organization is responsible for managing all the data and information generated during the verification testing. The Manufacturer is responsible for furnishing those records generated by the equipment testing organization. The NSF will be responsible for analysis and verification of the data.

A variety of data will be generated during a verification testing. Each piece of data or information identified for collection in the NSF Equipment Verification Testing Plan will need to be provided to the NSF. The data management section of the Manufacturer Field Operations Document should describe what types of data and information needs to be collected and managed. It should also describe how the data will be reported to the NSF for evaluation.

Laboratory Analyses: The raw data and the validated data must be provided to the NSF. These data should be provided in hard copy and in electronic format. As with the data generated by the innovative equipment, the electronic copy of the laboratory data should be provided in either a spreadsheet or a database format, and a data dictionary should be provided. In addition, all QA/QC summary forms must be provided in a hardcopy format.

Other items that must be provided include:

- field notebooks;
- photographs, slides and videotapes (copies);
- results from the use of other field analytical methods;

7.2 Report of Equipment Testing

The qualified testing organization shall prepare a draft report describing the verification testing that was carried out and the results of that testing. This report shall include the following topics:

- Introduction
- Executive Summary
- Description and Identification of Product Tested

- Procedures and Methods Used in Testing
- Results and Discussion
- Conclusions and Recommendations
- References
- Appendices
    - Manufacturer Field Operations Document
    - QA/AC Results

The NSF will review the draft report, the results of testing, the QA/QC results, and will prepare a final report.

Content of Manufacturer Field Operations Document Regarding Data Management and Analysis, and Reporting:

The Manufacturer shall be responsible for including the following elements in the Manufacturer Field Operations Document:

- *Description of what types of data and information needs to be collected and managed.*
- *Description of how the data will be reported to the NSF for evaluation.*

8.0 SAFETY AND ENVIRONMENTAL MEASURES

The testing organization shall prepare a document identifying the safety procedures that shall be used during the field work. The safety considerations addressed in this document will include the following as applicable:

- conformance with electrical and plumbing codes applicable at the test site(s);
- arsenic handling procedures (if spiking tests are to be performed) and disposal of wastes containing arsenic;
- ventilation of equipment or of trailers or buildings housing equipment, if there are gases generated by the equipment that could present a safety hazard (one example is the use of ozone).

Content of Manufacturer Field Operations Document Regarding Safety:

The Manufacturer Field Operations Document shall address safety and environmental considerations that are appropriate for the equipment being tested.